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Technical Feasibility of Producing Particleboard from Black Hills Ponderosa Pine

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Particleboards that met standard requirements for interior uses (floor underlayment, D-2 mobile home decking, and coreboard) and for exterior uses (bracing, siding, combination siding-sheathing, and combination subfloor underlayment) were made from ponderosa pine mill and logging residues in the laboratory. Six different types of board with varying particle geometry and distribution and with different resin contents and board densities were tested.

Keywords: Particleboard, wood waste, wood-using industries, *Pinus ponderosa.*

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INTRODUCTION

In recent years, both private companies and public groups have expressed interest in particleboard production in the Black Hills region of South Dakota and Wyoming. Since this kind of industry appears to offer a needed means of expanding and diversifying timber utilization in the Black Hills, the U.S. Forest Service has initiated a series of studies to help evaluate the feasibility of such production. The study described here was designed to identify specific types of particleboard that can meet market and building code requirements, can be manufactured by existing or foreseeable processes, and could utilize locally available wood materials. Subsequent phases of the overall analysis will include: (1) market potentials, (2) amounts and kinds of raw material available, (3) required manpower, (4) plant investment and operating economics, and (5) economic and environmental impact on the community.

In previous technical evaluations, Barger and Fleischer[2] and Wangaard et al.[3] reported that boards manufactured from ponderosa pine with urea resin have suitable properties for floor underlayment and core stock. Also, since ponderosa pine particleboard is manufactured and widely marketed for furniture core stock and other uses, it must be assumed that these boards meet the technical requirements of the trade. However, complete data on the wide variety of particleboards that can potentially be made from ponderosa pine were not available in the literature. The overall objective of the technical phase of this study was therefore to determine the characteristics of six different types of particleboard manufactured from various combinations of sawmill and logging residues to meet the technical requirements of selected end uses. Specific objectives were to determine the effect of geometry and distribution of particles and type and amount of resin on mechanical and physical properties.

METHODS

Sampling Raw Wood

A total sample of approximately 2,200 pounds of ponderosa pine (*Pinus ponderosa*) sawmill and forest residues was drawn at four sawmills and one logging site. All of the slabs, edgings, fine sawmill residues, and logging residue (tops) were sampled from freshly cut logs and trees. Planer shavings came from kiln-dried lumber.

Size distribution of the fine sawmill residues was determined with standard sieve screens. From geometrical shape and percentage of residues retained on each sieve (fig. 1), it is obvious that the sawing method used affected the character of the fine residues. Sawmill D, with a higher percentage of bigger particles, sawed with both chipping and circular headrigs; the other three mills used either circular or band headrigs with sashgang resaws.

The debarked slabs and edgings sampled were similar in appearance to those normally found at any Black Hills sawmill. The average specific gravity of these coarse residues was 0.39, ovendry-weight and green-volume basis.

The logging residues were 14 top sections of trees harvested from a multiproduct sale. Some of the bolts were more irregular in shape than others, and contained large knots representative of those from big, yellow-bark ponderosa pine trees (fig. 2). Saw-log trees had been utilized to a 6-inch top, and the small roundwood trees to about a 3.5-inch top. The tops had an average increment growth of 10.3 rings per inch and an average specific gravity of 0.40, ovendry-weight and green-volume basis. The diameter inside the bark at small ends of bolts ranged from 2.6 to 5.0 inches.

[2] Barger, Roland L., and Herbert O. Fleischer. 1964. New products from low-grade ponderosa pine timber. U.S. For. Serv. Res. Pap. RM-10, 54 p. Rocky Mt. For. and Range Exp. Stn., Fort Collins, Colo.

[3] Wangaard, F. F., F. C. Shirley, H. E. Troxell, R. S. Whaley, D. E. Eagen, and W. R. Wilcox. 1971. Potential markets for particleboard produced in the Rocky Mountains - Phase I. Unpublished report, Colorado State Univ., Dep. of Forest and Wood Sciences, Tech. Rep. Phase I. Rocky Mt. Forest and Range Exp. Stn. Res. Agreement 16-229-CT, CSU Project No. 1473, 34 p.

SCREEN OPENING (INCHES)

+1/4 +1/8 +1/16 -1/16

PLANER SHAVINGS

Sawmill A

Sawmill B

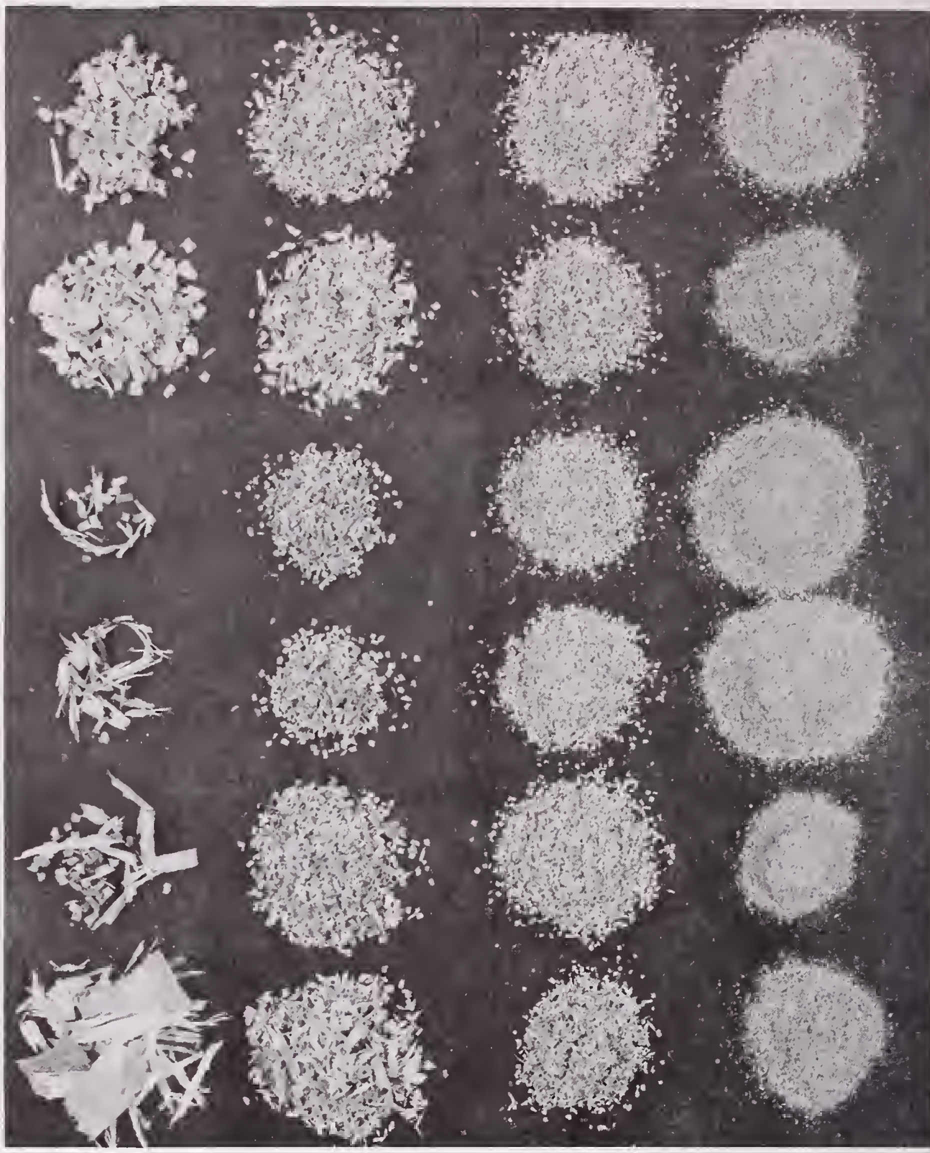
FINE SAWMILL RESIDUES OTHER THAN PLANER SHAVINGS

Sawmill A

Sawmill B

Sawmill C

Sawmill D



	PERCENTAGE RETAINED ON EACH SCREEN AND THE PAN			
PLANER SHAVINGS				
Sawmill A	7.4	19.9	34.1	38.6
Sawmill B	27.5	31.2	21.0	20.3
FINE SAWMILL RESIDUES OTHER THAN PLANER SHAVINGS				
Sawmill A	.1	2.1	37.9	59.9
Sawmill B	1.8	11.3	30.0	56.9
Sawmill C	9.0	38.7	39.1	13.2
Sawmill D	40.1	24.8	19.3	15.8

Figure 1.—Shape of planer shavings and other fine sawmill residues retained on each screen and the pan for each of four sawmills in the Black Hills, South Dakota.

Figure 2.—Four-foot bolts cut from ponderosa pine logging residues (tops only) on a multiproduct sale in the Black Hills, South Dakota.

Selecting Experimental Design and Panel Manufacture

The six panel types selected for study are described below. Types 1 and 2 are interior boards with particle geometry and distribution and urea formaldehyde (UF) binder typical of most boards currently being marketed. Type 3, an exterior board, is similar to type 2 except the binder is phenol formaldehyde (PF). Types 4, 5, and 6 are exterior and structural types. Types 4 and 5 are experimental boards that should more efficiently utilize available raw materials than a homogeneous waferboard as represented by type 6.

Interior Panel Types—UF Binder

Type 1.—Homogeneous fibrous board from solid wood residues.[4]

Type 2.—Three-layer commodity board, with faces of fine particles and core of coarse particles from refined shavings, sawdust, slabs, edgings, etc.[5]

[4]Includes slabs, edgings, and logging residues (without bark).

[5]Residues in panels 2-5 used in proportions as in actual availability (50 percent solid wood, 31 percent sawdust, and 19 percent shavings).

Exterior Panel Types—PF Binder

Type 3.—Three-layer commodity board, similar to type 2, except bonded with PF resin.

Type 4.—Three-layer flakeboard, with faces of larger flakes from solid wood residues processed through a ring flaker, and core of small flakes and refined shavings and sawdust.

Type 5.—Three-layer waferboard, with faces of wafers from solid wood residues processed through a disk flaker; cores similar to type 4. Wafer implies a large, flat flake 0.020-0.025 inch thick, 1.5 to 2 inches long, and of variable width.

Type 6.—Homogeneous waferboard, with wafers prepared from solid wood residues[4] processed through a disk flaker.

The study was conducted as a series of small factorial experiments, each of which pertained to one of the six panel types. Experimental variables for each factorial design were two levels of board density (40 to 45 pounds per cubic foot); two levels of resin content (6 and 10 percent in panel types 1, 2, and 3; 3 and 5 percent in panel types 4, 5, and 6). Duplicate panels were prepared at each level for a total of eight panels per type. Thus, a total of 48 panels (six types x two densities x two resin contents x two replications) were prepared in the study.

The panels were manufactured generally according to standard laboratory procedures as follows:

Panel size:
Rough—1/2 by 24 by 28 inches
Trimmed—1/2 by 22-1/4 by 26 inches.
Density:
40 or 45 pounds per cubic foot (lb/in^3, based on ovendry weight and volume at 65 percent relative humidity (RH).
Resin content:
6 or 10 percent, types 1, 2, and 3; 3 or 5 percent, types 4, 5, and 6 (based on ovendry weight of wood).
Wax content:
1/2 percent in UF panels, 1 percent in PF panels (based on ovendry weight of wood).
Catalyst:
1 percent in UF panels only (buffered 20 percent ammonium chloride solution).
Mat moisture content:
10 $\pm$ 1/2 percent in UF panels (ovendry basis); 8 $\pm$ 1/2 percent in PF panels (ovendry basis).
Press closing time:
1 minute to thickness.
Press cycle:
5 minutes at 325° F for UF panels; 7 minutes at 400° F for PF panels (high-density panels of type 6 were pressed 10 minutes at 300° F to avoid blisters).
Posttreatment:
UF panels were cooled immediately, PF panels were hot-stacked overnight in insulated box.

Evaluating Specimens

The following specimens were cut from each of the 48 panels (numbers in brackets indicate the number of evaluations for each panel):

Specimen 1: Static bending [2]
Modulus of elasticity (MOE).
Modulus of rupture (MOR).
Specimen 2: Internal bond [2]
Specimen 3: Humidity exposure—50-90 and 30-90 percent RH [2]
Linear expansion.
Thickness swelling.
Moisture absorption.
Specimen 4: 24-hour water soak [2]
Linear expansion.
Thickness swelling.
Moisture absorption.
Specimen 5: Nailing properties [*1*]
Direct nail withdrawal.
Nailhead pullthrough.
Lateral nail resistance—3/8- and 1/2-inch edge distance.
Specimen 6: Accelerated aging—Panel types 3, 4, 5, 6 [2]
Modulus of elasticity.[6]
Modulus of rupture.[6]
Internal bond strength.
Specimen 7: Direct screw withdrawal—Panel types 1 and 2 [2]
Face resistance.
Edge resistance.
Specimen 8: Hardness [*4*]

Specimens 1, 2, 5, 6, 7, and 8 were conditioned to equilibrium moisture content at 80° F and 65 percent RH before testing; all were tested according to procedures specified in ASTM D 1037-72a.[7]

RESULTS

The study results are presented and interpreted to compare the performance of the test boards (1) with each other, and (2) with current end-use standards. The latter comparison is particularly significant in selecting the most favorable product or products for the Black Hills area. Since some end uses do not require as high technical performance as others, it is critical to economic feasibility to keep the cost of manufacturing boards consistent with the end use and competitive with other products.

The boards were also tested for properties other than those required for present end uses, including some that may be required in revised standards for existing end uses or for new applications. The mean values for each property, together with the pooled error variance for each combination of board type, resin content, and density, are reported in table 1. The means are based on four observations except for nail withdrawal, nailhead pullthrough, and lateral nail resistance (two observations each), and hardness (eight observations).

Factorial analyses of the test data for the interior-type boards indicate that the three-layer commodity board surpassed the homogeneous fibrous board in modulus of elasticity (MOE), internal bond, hardness, and screw holding on both edge and face, but not in modulus of rupture (MOR) or nailing properties. The three-layer commodity board also had lower water absorption and thickness swell, but higher linear expansion, than the homogeneous board. The analysis also indicates that the boards with 10 percent resin had higher MOE, MOR, internal bond, hardness, screw holding on the edge and faces, and nailing properties than those with 6 percent resin. Resin

[6]*Calculations of values based on specimen thickness before accelerated aging as specified in CS 236-66, SEC. 3.4.2.*

[7]*1972 Annual Book of ASTM Standards, Part 16, D 1037-72a.*

Table 1.--Test properties of the six particleboaru types, with low and high resin contents and panel densities--mean values and pooled error variances (average of four evaluations except as indicated)

Type and resin content	Board density	Accelerated aging: Modulus of elasticity Before	Modulus of elasticity After[1]	Modulus of rupture Before	Modulus of rupture After[1]	Internal bond Before	Internal bond After[1]	Linear expansion 50-90% RH	Linear expansion 30-90% RH	Linear expansion 24-hr water soak	Thickness swelling 50-90% RH	Thickness swelling 30-90% RH	Thickness swelling 24-hr water soak	Moisture absorption 50-90% RH	Moisture absorption 30-90% RH	Moisture absorption 24-hr water soak	Nailing properties: With-drawal	Pull-through	Lateral resistance[2] 3/8"	Lateral resistance[2] 1/2"	Screw-holding resistance[2] Edge	Screw-holding resistance[2] Face	Hardness[3]
	*lb/ft*³	*lb/in*²(10³)		- - - *lb/in*² - - -				- - - - - - - - - - - - - *Percent* - - - - - - - - - - - -									- - - - - - - - *lb* - - - - - - - -						
TYPE 1.--INTERIOR HOMOGENEOUS FIBROUS BOARD																							
Resin, 6%	40	262	--	2170	--	40	--	0.21	0.27	0.30	19.7	21.3	59.3	8.8	10.9	141.3	42	248	255	300	150	157	555
	45	341	--	3470	--	57	--	.14	.20	.26	12.4	13.9	45.6	7.6	9.5	95.8	45	338	329	453	192	234	865
10%	40	338	--	3600	--	82	--	.14	.21	.27	8.1	9.1	24.4	7.1	9.0	88.4	44	297	359	438	214	239	715
	45	437	--	4160	--	108	--	.13	.22	.23	6.4	7.3	16.1	6.6	8.4	58.4	75	416	436	493	271	283	880
Pooled error variance		605	--	120553	--	83.4	--	.0001	.0001	.0003	2.03	1.85	.385	.131	.109	35.6	160	930	965	3591	561	893	6950
TYPE 2.--INTERIOR THREE-LAYER COMMODITY BOARD																							
Resin, 6%	40	359	--	2620	--	119	--	.26	.36	.14	9.8	10.8	8.9	7.8	9.9	17.3	48	331	346	397	271	276	555
	45	424	--	3260	--	175	--	.27	.37	.11	8.4	9.5	7.5	7.3	9.2	13.7	59	400	333	441	405	346	905
10%	40	409	--	3190	--	187	--	.23	.33	.15	7.0	8.0	6.2	7.4	9.4	16.6	55	340	398	476	342	370	815
	45	480	--	3840	--	234	--	.26	.37	.12	7.6	8.4	7.0	7.2	9.1	15.3	64	425	437	503	435	426	1075
Pooled error variance		820	--	70010	--	59.1	--	.0003	.0004	.0002	.340	.383	,161	.133	.157	1.98	19.9	585	510	592	1115	1579	8522
TYPE 3.--EXTERIOR THREE-LAYER COMMODITY BOARD																							
Resin, 6%	40	366	281	2680	2040	141	82	.18	.30	.18	10.0	11.5	7.9	9.9	12.8	28.0	44	280	223	283	--	--	745
	45	448	336	3360	2440	177	91	.16	.28	.17	9.8	11.3	8.2	10.1	12.8	29.8	56	345	266	347	--	--	883
10%	40	400	313	3100	2300	207	138	.17	.31	.26	7.4	8.6	9.3	11.3	14.1	49.9	59	337	288	364	--	--	840
	45	522	401	4030	3130	222	140	.19	.32	.13	7.1	8.2	8.1	10.9	13.4	48.6	51	403	335	422	--	--	1070
Pooled error variance		440	398	33991	29545	81.7	41.1	.0001	.0003	.0005	.177	.150	.525	.360	.366	10.4	305	412	376	445	--	--	13676
TYPE 4.--EXTERIOR THREE-LAYER FLAKEBOARD																							
Resin, 3%	40	393	245	2480	1370	73	10	.16	.25	.12	17.7	20.2	19.5	9.8	12.5	35.1	38	271	259	300	--	--	650
	45	489	354	3280	1570	107	8	.14	.23	.06	15.9	17.9	14.4	9.3	11.9	25.6	40	339	325	426	--	--	935
5%	40	433	357	3120	2400	160	65	.10	.20	.13	11.4	13.4	14.6	9.6	12.4	41.2	48	378	343	410	--	--	710
	45	526	419	3940	2990	181	78	.11	.20	.09	11.2	12.8	13.5	9.3	11.9	33.3	75	443	386	527	--	--	930
Pooled error variance		1765	4286	63199	71139	24.8	58.9	.0003	.0004	.0002	3.02	2.96	.315	.867	.884	11.4	72	2276	5273	3370	--	--	12074
TYPE 5.--EXTERIOR THREE-LAYER WAFERBOARD																							
Resin, 3%	40	539	413	3540	1490	81	6	.12	.21	.08	15.4	17.2	11.4	9.4	12.1	24.1	54	309	385	444	--	--	630
	45	720	547	5210	2090	108	7	.13	.22	.05	12.2	13.7	8.2	8.7	11.0	18.5	73	423	432	480	--	--	965
5%	40	573	603	4380	4000	152	52	.11	.19	.05	10.6	12.0	7.2	9.4	11.9	19.6	74	422	506	505	--	--	870
	45	704	643	5710	4500	145	24	.12	.22	.05	10.5	12.0	7.2	9.2	11.6	19.5	70	420	548	529	--	--	875
Pooled error variance		2794	2864	169158	167607	64.9	19.4	.0002	.0005	.0002	2.73	3.00	.225	.865	.957	3.39	272	2107	8621	3712	--	--	18053
TYPE 6.--EXTERIOR HOMOGENEOUS WAFERBOARD																							
Resin, 3%	40	646	559	4330	2780	72	5	.11	.19	.02	16.4	17.7	17.9	9.2	11.4	39.5	61	335	488	666	--	--	840
	45	674	624	4730	3720	74	8	.13	.20	.01	13.9	15.0	17.0	9.0	10.8	42.9	67	383	532	626	--	--	1080
5%	40	612	623	5150	4650	133	75	.11	.18	.02	10.8	11.6	9.8	9.3	11.3	23.4	80	467	511	684	--	--	1120
	45	680	637	5150	4970	143	99	.08	.15	.03	9.0	10.2	7.0	8.6	10.4	17.0	108	591	644	783	--	--	1150
Pooled error variance		2353	6064	175608	239400	66.9	86.5	.0001	.0002	.0001	.529	.529	1.12	.355	.353	1.62	159	9447	2536	20283	--	--	64566

[1]Based on thickness before aging.
[2]Average of two evaluations.
[3]Average of eight evaluations.

content also significantly interacted with board type to affect MOE, MOR, internal bond, linear expansion, thickness swell, and water absorption. Likewise, the boards of 45 density had higher MOE, MOR, internal bond, hardness, screw holding, and nailing properties than those of 40. Board density also interacted with board type to affect internal bond, screw holding on edge, linear expansion, thickness swell, and water absorption.

Analysis of the test data for the exterior-type boards shows that both the three-layer waferboard and the homogeneous waferboard had a higher MOE and MOR, both before and after accelerated aging, than the three-layer flakeboard and the three-layer commodity board. The latter type had the highest internal bond, however, both before and after accelerated aging, probably due to its higher resin content. The waferboards also had the highest nail-holding strength. The homogeneous waferboard was hardest.

The most conspicuous results were the low internal bond strength of the exterior boards made with 3 percent resin after accelerated aging. The mean values for these boards ranged from only 5 to 10 pounds per square inch (lb/in^2). Values for the same type of boards, both with 5 percent resin, ranged from 24 to 99 lb/in^2.

Analysis shows that boards made with 5 percent resin had higher MOR, internal bond, nail withdrawal, and nailhead pullthrough, and had lower thickness swell and linear expansion, than those with 3 percent resin. MOE was not significantly affected by increasing the resin content. Resin content also interacted with board density to affect hardness. The boards with 45 density had higher MOE, MOR, internal bond, hardness, nail withdrawal, and nailhead pullthrough, and had lower thickness swell than those with 40 density.

After accelerated aging, the 5 percent resin boards had higher MOE, MOR, and internal bond than those with 3 percent resin. Likewise, the 45 boards had higher MOE and MOR than the 40 boards after accelerated aging. Board density also interacted with board type to affect the internal bond.

Tables 2 and 3 show whether test properties of the different particleboards passed the standard requirements for the particular uses. These are shown as one-sided 0.99 confidence limits, upper or lower, depending on the particular test property.

Interior-Type End Uses

Only the homogeneous fibrous board, type 1, and the three-layer commodity board, type 2, both made with interior urea formaldehyde resin, were considered for these end uses.

Floor Underlayment

None of the homogeneous fibrous boards passed all of the floor underlayment requirements (table 2). The 6 percent urea, 40 combination was low in MOE, internal bond, and screw holding on both the face and edge. The thickness swell was especially high at 60 percent. The ~~8~~ 6 percent urea, 45 combination failed in internal bond, thickness swell, and screw holding on the face. The 10 percent urea, 40 board failed in thickness swelling and screw holding on the face. The 10 percent urea, 45 board passed all of the property tests except thickness swell; additional wax probably would have been beneficial in this board type.

All of the three-layer commodity boards met the requirements except the 6 percent urea, 40 board, which failed the statistical test in screw holding on the face by only 2 pounds (table 2). The mean screw-holding test value, however, exceeded the standard requirement by 51 pounds.

Mobile Home Decking, D-2 and D-3

None of the homogeneous fibrous boards had an adequate combination of properties for D-2 and D-3 decking. Mainly the MOE and internal bond were too low and thickness swell too high (table 2). None of the three-layer commodity board passed all of the D-3 requirements and only one—the 10 percent urea, 45 board—passed all of the D-2 requirements. Mainly the MOE was too low.

End Uses Requiring Performance in Accordance with CS 236-66

Type 1-B-1.—The property requirements specified in the Standard are the same as those for floor underlayment except for thickness swell, which is not specified for type 1-B-1 particleboard. Thus the results in table 2 and the discussion of results for floor underlayment apply equally well to 1-B-1 particleboard except for thickness swell. The markets for this board would include furniture, doors, kitchen cabinets, counter tops, and so forth.

Type 1-B-2.—The only homogeneous fibrous board passing all of the type 1-B-2 requirements was the 10 percent urea, 45 board. All other homogeneous fibrous boards were low in MOE and screw holding. Internal bond was also low for the 6 percent urea boards. MOR requirements were met by all boards except the 6 percent urea, 40 combination (table 2).

The only three-layer commodity board passing all the requirements was the 10 percent urea, 45 board. The others did not have adequate MOE, and the 6 percent urea, 40 board also lacked adequate MOR and screw holding on the face.

Table 2.--Test properties[1] of interior homogeneous fibrous boards and three-layer commodity boards compared with the standard requirements for floor underlayment, D-2 and D-3 mobile home decking, and Commercial Standard 236-66 (1-B-2)

Type and resin content	Board density	Modulus of elasticity	Modulus of rupture	Internal bond	Linear expansion 50-90% RH	Thickness swell	Screwholding resistance Edge	Screwholding resistance Face	Hardness
	lb/ft^3	*lb/in*^{2}	*lb/in*^{2}	*lb/in*^{2}	*Percent*	*Percent*	*lb*	*lb*	*lb*
STANDARD REQUIREMENT FOR FLOOR UNDERLAYMENT[2]		≥250,000	≥1,600	≥70	≤0.35%	≤0.063 in. 10%	≥160	≥225	--
TYPE 1.--INTERIOR HOMOGENEOUS FIBROUS BOARD									
Resin, 6%	40	229,000	1,705	28	.22	60	118	117	
	45	308,000	3,005	45	.15	47	160	194	
10%	40	305,000	3,135	70	.15	25	182	199	
	45	404,000	3,695	96	.14	17	239	243	
TYPE 2.--INTERIOR THREE-LAYER COMMODITY BOARD									
Resin, 6%	40	321,000	2,265	109	.28	10	226	223	
	45	386,000	2,905	165	.29	8	360	293	
10%	40	371,000	2,835	177	.25	7	297	317	
	45	442,000	3,485	224	.28	8	390	373	
STANDARD REQUIREMENT FOR D-2 MOBILE HOME DECKING[3]		≥400,000	≥2,400	≥80	≤0.30%	≤8%	--	--	≥500
TYPE 1.--INTERIOR HOMOGENEOUS FIBROUS BOARD									
Resin, 6%	40	229,000	1,705	28	.22	60	--	--	482
	45	308,000	3,005	45	.15	47	--	--	792
10%	40	305,000	3,135	70	.15	25	--	--	642
	45	404,000	3,695	96	.14	17	--	--	807
TYPE 2.--INTERIOR THREE-LAYER COMMODITY BOARD									
Resin, 6%	40	321,000	2,265	109	.28	10	--	--	474
	45	386,000	2,905	165	.29	8	--	--	824
10%	40	371,000	2,835	177	.25	7	--	--	734
	45	442,000	3,485	224	.28	8	--	--	994
STANDARD REQUIREMENT FOR D-3 MOBILE HOME DECKING[3]		≥450,000	≥2,800	≥80	≤0.30%	≤8%	--	--	≥500
TYPE 1.--INTERIOR HOMOGENEOUS FIBROUS BOARD									
Resin, 6%	40	229,000	1,705	28	.22	60	--	--	482
	45	308,000	3,005	45	.15	47	--	--	792
10%	40	305,000	3,135	70	.15	25	--	--	642
	45	404,000	3,695	96	.14	17	--	--	807
TYPE 2.--INTERIOR THREE-LAYER COMMODITY BOARD									
Resin, 6%	40	321,000	2,265	109	.28	10	--	--	474
	45	386,000	2,905	165	.29	8	--	--	824
10%	40	371,000	2,835	177	.25	7	--	--	734
	45	442,000	3,485	224	.28	8	--	--	994
STANDARD REQUIREMENT FOR COMMERCIAL STANDARD 236-66 (1-B-2)		≥400,000	≥2,400	≥60	≤0.30%	--	≥200	≥225	
TYPE 1.--INTERIOR HOMOGENEOUS FIBROUS BOARD									
Resin, 6%	40	229,000	1,705	28	.22	--	118	117	
	45	308,000	3,005	45	.15	--	160	194	
10%	40	305,000	3,135	70	.15	--	182	199	
	45	404,000	3,695	96	.14	--	239	243	
TYPE 2.--INTERIOR THREE-LAYER COMMODITY BOARD									
Resin, 6%	40	321,000	2,265	109	.28	--	226	223	
	45	386,000	2,905	165	.29	--	360	293	
Resin, 10%	40	371,000	2,835	177	.25	--	297	317	
	45	442,000	3,485	224	.28	--	390	373	

[1]One-sided 0.99 confidence limits, upper or lower depending on the test property, were compared with the standard requirements. The property values not passing the standards are underlined.
[2]Commercial Standard CS 236-66; FHA Interim Revision No. 52 705-9.1, June 1971.
[3]National Particleboard Association Standard NPA 1-71.

Table 3.--Test properties[1] of exterior particle boards (types 3-6) compared with the standard requirements for bracing, siding, and combination siding-sheathing, and with those for combination subfloor underlayment

Type and resin content	Board density	Modulus of elasticity	Modulus of rupture	Internal bond	Linear expansion 50-90% RH	Hardness
	lb/ft³	- - - - *lb/in²* - - - -			*Percent*	*lb*
STANDARD REQUIREMENT FOR BRACING, SIDING, AND COMBINATION SIDING-SHEATHING[2]		≥250,000	≥1,800	≥65	≤0.35%	≥500
TYPE 3.--EXTERIOR THREE-LAYER COMMODITY BOARD						
Resin 6%	40	338,000	2,433	129	.19	642
	45	420,000	3,113	165	.17	780
10%	40	372,000	2,853	195	.18	737
	45	494,000	3,783	210	.20	967
TYPE 4.--EXTERIOR THREE-LAYER FLAKEBOARD						
Resin 3%	40	337,000	2,143	66	.18	553
	45	433,000	2,943	100	.16	838
5%	40	377,000	2,783	153	.12	613
	45	470,000	3,603	174	.13	833
TYPE 5.--EXTERIOR THREE-LAYER WAFERBOARD						
Resin 3%	40	468,000	2,989	70	.14	512
	45	649,000	4,659	97	.15	847
5%	40	502,000	3,829	141	.13	752
	45	633,000	5,159	134	.14	757
TYPE 6.--EXTERIOR HOMOGENEOUS WAFERBOARD						
Resin 3%	40	581,000	3,768	61	.12	616
	45	609,000	4,168	63	.14	856
5%	40	547,000	4,588	122	.12	896
	45	615,000	4,588	132	.09	926
STANDARD REQUIREMENT FOR COMBINATION SUBFLOOR UNDERLAYMENT[3]		≥450,000	≥2,500	≥60	≤0.35%	≥500
TYPE 3.--EXTERIOR THREE-LAYER COMMODITY BOARD						
Resin 6%	40	338,000	2,433	129	.19	642
	45	420,000	3,133	165	.17	780
10%	40	372,000	2,853	195	.18	737
	45	494,000	3,783	210	.20	967
TYPE 4.--EXTERIOR THREE-LAYER FLAKEBOARD						
Resin 3%	40	337,000	2,143	66	.18	553
	45	433,000	2,943	100	.16	838
5%	40	377,000	2,783	153	.12	613
	45	470,000	3,603	174	.13	833
TYPE 5.--EXTERIOR THREE-LAYER WAFERBOARD						
Resin 3%	40	468,000	2,989	70	.14	512
	45	649,000	4,659	97	.15	847
5%	40	502,000	3,829	141	.13	752
	45	633,000	5,159	134	.14	757
TYPE 6.--EXTERIOR HOMOGENEOUS WAFERBOARD						
Resin 3%	40	581,000	3,768	61	.12	616
	45	609,000	4,168	63	.14	856
5%	40	547,000	4,588	122	.12	896
	45	615,000	4,588	132	.09	926

[1]One-sided 0.99 confidence limits, upper or lower depending on the test property, were compared with the standard requirements. The property values not passing the standards are underlined.

[2]FHA Use of Materials, No. UM32, June 1961; Uniform Building Code, 1970 edition; and FHA Tech. Circ. No. 12.

[3]FHA Use of Materials, No. UM57, and National Particleboard Association Standard NPA 2-70.

Exterior-Type End Uses

All the boards manufactured with exterior phenol formaldehyde resin were considered for these end uses.

Bracing, Siding, and Combination Siding-Sheathing

All of the exterior three-layer commodity boards exceeded the property requirements listed in table 3 for the above uses. The internal bonds for these boards were especially high. Likewise, all of the three-layer flakeboards and three-layer waferboards exceeded property requirements. The homogeneous waferboards likewise performed satisfactorily, except for the 3 percent resin, 40 and 45 boards. The internal bond of these boards was low.

Combination Subfloor Underlayment for Factory-Built Modular Housing

The only three-layer commodity board with a high enough MOE plus adequate values in other properties was the 10 percent resin, 45 board (table 3). The MOR for the 6 percent resin, 40 board was also low.

Similarly, the only three-layer flakeboard having high enough MOE and adequate values in other properties for these end uses was the 5 percent resin, 45 board. The MOR was also low for the 3 percent resin, 40 board. All of the three-layer waferboards and the homogeneous waferboards exceeded standard requirements.

End Uses Requiring Accelerated Aging Test

Some exterior uses require particleboard to pass the accelerated aging test as specified in Commercial Standard CS 236-66 in addition to the other requirements. The Standard states that the minimum MOR after aging should be not less than 50 percent of the original minimum average MOR. All boards passed the accelerated aging requirement except three — the 45 three-layer flakeboard and the 40 and 45 three-layer waferboards with 3 percent resin (table 4). The internal bond of these three boards was also low after accelerated aging.

Table 4.--Modulus of rupture of exterior particleboard, before and after accelerated aging[1]

Type and resin content	Board density	Modulus of rupture: Before	Modulus of rupture: After
	lb/ft^3	*lb/ft*^{2}	*lb/ft*^{2}
TYPE 3.--EXTERIOR THREE-LAYER COMMODITY BOARD			
Resin 6%	40	2,680	2,040
	45	3,360	2,440
10%	40	3,100	2,300
	45	4,030	3,130
TYPE 4.--EXTERIOR THREE-LAYER FLAKEBOARD			
Resin 3%	40	2,480	1,370
	45	3,280	1,570
5%	40	3,120	2,400
	45	3,940	2,990
TYPE 5.--EXTERIOR THREE-LAYER WAFERBOARD			
Resin 3%	40	3,540	1,490
	45	5,210	2,090
Resin 5%	40	4,380	4,000
	45	5,710	4,500
TYPE 6.--EXTERIOR HOMOGENEOUS WAFERBOARD			
Resin 3%	40	4,330	2,780
	45	4,730	3,720
5%	40	5,150	4,650
	45	5,150	4,970

[1]When the accelerated aging test is required, the standard states that the minimum mean modulus of rupture of the samples ahll not be less than 50% of minimum mean modulus of rupture of samples not exposed to the aging test, Commercial Standard CS 236-66. The property values not passing the standards are underlined.

CONCLUSIONS

We made experimental particleboards that met standard requirements for interior uses (floor underlayments, D-2 mobile home decking, and coreboard) and for exterior uses (bracing, siding, combination siding-sheathing, and combination subfloor underlayment) from mill and logging residues of Black Hills ponderosa pine. The acceptability of each board type, resin content, and board density combination for these uses is summarized in tables 5 and 6. Also noted in table 5 are the boards rejected only because of thickness swell. Acceptability is based upon requirements and performances previously described.

The three-layer interior commodity board with 6 percent resin and density of 40 should be investigated further for both floor underlayment and uses requiring type 1-B-1 performance. The board passed all property requirements for the two uses except screw holding on the face, which was nearly acceptable (see table 2). This board closely resembles the typical commercial "commodity" type board being mass produced for these two uses in both raw material and other manufacturing characteristics.

Table 5.--Acceptability of interior particleboards for floor underlayment, D-2 and D-3 mobile home decking, and other uses that require the performance of boards 1-B-1 and 1-B-2 in Commercial Standard CS 236-66

Type and resin content		Board density	Floor underlayment	Mobile home decking		Uses that require CSC 236-66 performance	
				D-2	D-3	1-B-1	1-B-2
TYPE 1.--INTERIOR HOMOGENEOUS FIBROUS BOARD							
Resin	6%	40	No	No	No	No	No
		45	No	No	No	No	No
	10%	40	No	No	No	No	No
		45	No[1]	No[1]	No	Yes	Yes
TYPE 2.--INTERIOR THREE-LAYER COMMODITY BOARD							
Resin	6%	40	No[2]	No	No	No[2]	No
		45	Yes	No	No	Yes	No
	10%	40	Yes	No	No	Yes	No
		45	Yes	Yes	No	Yes	Yes

[1]Rejected because of thickness swell.
[2]Failed statistical test by only 2 pounds in screwholding on face.

Table 6.--Acceptability of exterior particleboards for bracing, siding, combination siding-sheathing, and for combination subfloor underlayment

Type and resin content		Board density	Bracing, siding, and combination siding-sheathing	Combination subfloor underlayment
TYPE 3.--EXTERIOR THREE-LAYER COMMODITY BOARD				
Resin	6%	40	Yes	No
		45	Yes	No
	10%	40	Yes	No
		45	Yes	Yes
TYPE 4.--EXTERIOR THREE-LAYER FLAKEBOARD				
Resin	3%	40	Yes	No
		45	Yes	No
	5%	40	Yes	No
		45	Yes	Yes
TYPE 5.--EXTERIOR THREE-LAYER WAFERBOARD				
Resin	3%	40	Yes	Yes
		45	Yes	Yes
	5%	40	Yes	Yes
		45	Yes	Yes
TYPE 6.--EXTERIOR HOMOGENEOUS WAFERBOARD				
Resin	3%	40	No	Yes
		45	No	Yes
	5%	40	Yes	Yes
		45	Yes	Yes

It appears that a resin content of 3 percent is not high enough to develop adequate internal bonds for boards exposed to exterior conditions simulated by the accelerated aging test. Boards with 5 or more percent resin performed well, however, when exposed to accelerated aging (see table 1).

It is important to note that the two conventional exterior board types—three-layer commodity and three-layer flakeboard—both performed as adequately as the three-layer waferboard and the homogeneous waferboard for the exterior uses of bracing, siding, and combination siding-sheathing.

Also of importance was the adequate performance of the 45 three-layer flakeboard with 5 percent resin for combination subfloor underlayment uses. These conventional boards can be manufactured with lower cost raw material from large residue surpluses in most lumber and plywood manufacturing areas. Typically, stumpage and harvesting costs are not charged against these residues. Only the costs of handling the residues and hauling them from the sawmill or plywood plant to the particleboard plant are charged. By contrast, when roundwood is used, the particleboard operation must pay the total cost of stumpage, harvesting, hauling, and handling.

Markstrom, Donald C., William F. Lehmann, and J. Dobbin McNatt. 1976. Technical feasibility of producing particleboard from Black Hills ponderosa pine. USDA For. Serv. Res. Pap. RM-173, 10 p. Rocky Mt. For. and Range Exp. Stn., Fort Collins, Colo. 80521.

Particleboards that met standard requirements for interior uses (floor underlayment, D-2 mobile home decking, and coreboard) and for exterior uses (bracing, siding, combination siding-sheathing, and combination sub-floor underlayment) were made from ponderosa pine mill and logging residues in the laboratory. Six different types of board with varying particle geometry and distribution and with different resin contents and board densities were tested.

Keywords: Particleboard, wood waste, wood-using industries, *Pinus ponderosa.*

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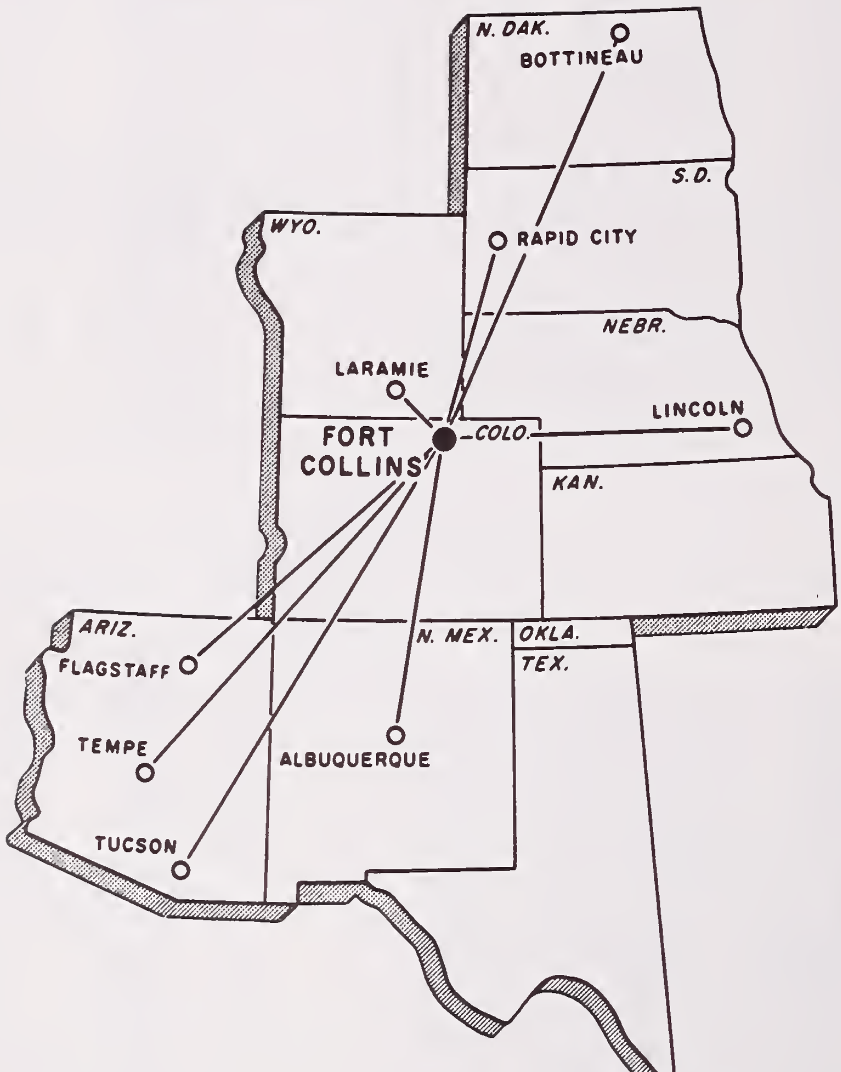
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